



Chromosome 21

Humans normally have 46 chromosomes in each cell, divided into 23 pairs. Two copies of chromosome 21, one copy inherited from each parent, form one of the pairs. Chromosome 21 is the smallest human chromosome, spanning about 48 million base pairs (the building blocks of DNA) and representing 1.5 to 2 percent of the total DNA in cells.

In 2000, researchers working on the Human Genome Project announced that they had determined the sequence of base pairs that make up this chromosome. Chromosome 21 was the second human chromosome to be fully sequenced.

Identifying genes on each chromosome is an active area of genetic research. Because researchers use different approaches to predict the number of genes on each chromosome, the estimated number of genes varies. Chromosome 21 likely contains 200 to 300 genes that provide instructions for making proteins. These proteins perform a variety of different roles in the body.

Health Conditions Related to Chromosomal Changes

The following chromosomal conditions are associated with changes in the structure or number of copies of chromosome 21.

Core binding factor acute myeloid leukemia

A genetic rearrangement (translocation) involving chromosome 21 is associated with a type of blood cancer known as core binding factor acute myeloid leukemia (CBF-AML). This rearrangement occurs in approximately 7 percent of acute myeloid leukemia cases in adults. The translocation, written as t(8;21), fuses part of the *RUNX1* gene from chromosome 21 with part of the *RUNX1T1* gene (also known as *ETO*) from chromosome 8. This mutation is acquired during a person's lifetime and is present only in certain cells. This type of genetic change, called a somatic mutation, is not inherited.

The fusion protein produced from the t(8;21) translocation, called RUNX1-ETO, retains some functions of the two individual proteins. The normal RUNX1 protein, produced from the *RUNX1* gene, is part of a protein complex called core binding factor (CBF) that attaches (binds) to DNA and turns on genes involved in blood cell development. The normal ETO protein, produced from the *RUNX1T1* gene, turns off gene activity. The RUNX1-ETO fusion protein forms CBF and attaches to DNA, but instead of turning on genes that stimulate the development of blood cells, it turns those genes off. This change in gene activity blocks the maturation (differentiation) of blood cells and leads to the production of abnormal, immature white blood cells called myeloid blasts. While t(8;21) is important for leukemia development, one or more

additional genetic changes are typically needed for the myeloid blasts to develop into cancerous leukemia cells.

Down syndrome

Down syndrome is a chromosomal condition that is associated with intellectual disability, a characteristic facial appearance, and weak muscle tone (hypotonia) in infancy. This condition is most often caused by trisomy 21. Trisomy 21 means that each cell in the body has three copies of chromosome 21 instead of the usual two copies.

Less commonly, Down syndrome occurs when part of chromosome 21 becomes attached (translocated) to another chromosome during the formation of reproductive cells (eggs and sperm) or very early in fetal development. Affected people have two copies of chromosome 21 plus extra material from chromosome 21 attached to another chromosome, resulting in three copies of genetic material from chromosome 21. Affected individuals with this genetic change are said to have translocation Down syndrome.

In a very small percentage of cases, Down syndrome results from an extra copy of chromosome 21 in only some of the body's cells. In these people, the condition is called mosaic Down syndrome.

Researchers believe that having extra copies of genes on chromosome 21 disrupts the course of normal development, causing the characteristic features of Down syndrome and the increased risk of health problems associated with this condition.

Other cancers

Translocations of genetic material between chromosome 21 and other chromosomes have been associated with several types of cancer. For example, acute lymphoblastic leukemia (a type of blood cancer most often diagnosed in childhood) has been associated with a translocation between chromosomes 12 and 21.

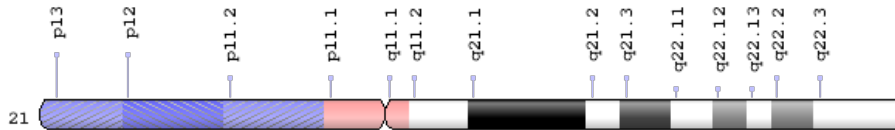
Other chromosomal conditions

Other changes in the number or structure of chromosome 21 have a variety of effects on health and development. Chromosome 21 abnormalities can cause intellectual disability, delayed development, and characteristic facial features. In some cases, the signs and symptoms are similar to those of Down syndrome.

Changes involving chromosome 21 can include a missing segment of the chromosome in each cell (partial monosomy 21) and a circular structure called ring chromosome 21. A ring chromosome occurs when a chromosome breaks in two places and the ends of the chromosome arms fuse together to form a circular structure.

Chromosome Diagram

Geneticists use diagrams called idiograms as a standard representation for chromosomes. Idiograms show a chromosome's relative size and its banding pattern, which is the characteristic pattern of dark and light bands that appears when a chromosome is stained with a chemical solution and then viewed under a microscope. These bands are used to describe the location of genes on each chromosome.



Credit: Genome Decoration Page/NCBI

Additional Information & Resources

MedlinePlus

- Encyclopedia: Chromosome
<https://medlineplus.gov/ency/article/002327.htm>

Additional NIH Resources

- National Human Genome Research Institute: Chromosome Abnormalities
<https://www.genome.gov/11508982/>
- National Human Genome Research Institute: Down Syndrome Research Expedited by Decoding of Human Chromosome 21 - Second Human Chromosome Sequenced by the Human Genome Project (May 2000)
<https://www.genome.gov/10001485/>

Scientific Articles on PubMed

- PubMed
<https://www.ncbi.nlm.nih.gov/pubmed?term=%28Chromosomes,+Human,+Pair+21%5BMAJR%5D%29+AND+%28Chromosome+21%5BTI%5D%29+AND+english%5Bla%5D+AND+human%5Bmh%5D+AND+%22last+720+days%22%5Bdp%5D>

Research Resources

- Cancer Genetics Web
<http://www.cancerindex.org/geneweb/clinkc21.htm>
- Database of Genomic Variants: Chromosome 21
http://projects.tcag.ca/variation/cgi-bin/tbrowse/tbrowse?source=hg17&table=Locus&show=table&keyword=&flop=AND&fcol=_C19&fcomp==&fkwd=chr21&cols=

- Ensembl Human Map View: Chromosome 21
http://www.ensembl.org/Homo_sapiens/Location/Chromosome?chr=21;r=21:1-46709983
- HUGO Gene Nomenclature Committee: Statistics & Downloads for Chromosome 21
<https://www.genenames.org/cgi-bin/statistics?c=21/>
- The DNA sequence of human chromosome 21. *Nature*. 2000 May 18;405(6784):311-9.
<https://www.nature.com/articles/35012518.pdf>
- U.S. Department of Energy: Human Genome Project Information Archive
https://web.ornl.gov/sci/techresources/Human_Genome/posters/chromosome/chromo21.shtml

Sources for This Summary

- Antonarakis SE, Lyle R, Dermitzakis ET, Reymond A, Deutsch S. Chromosome 21 and down syndrome: from genomics to pathophysiology. *Nat Rev Genet*. 2004 Oct;5(10):725-38. Review.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/15510164>
- Antonarakis SE, Lyle R, Deutsch S, Reymond A. Chromosome 21: a small land of fascinating disorders with unknown pathophysiology. *Int J Dev Biol*. 2002 Jan;46(1):89-96. Review.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/11902692>
- Antonarakis SE. Chromosome 21: from sequence to applications. *Curr Opin Genet Dev*. 2001 Jun;11(3):241-6. Review.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/11377958>
- Aït Yahya-Graison E, Aubert J, Dauphinot L, Rivals I, Prieur M, Golfier G, Rossier J, Personnaz L, Creau N, Bléhaut H, Robin S, Delabar JM, Potier MC. Classification of human chromosome 21 gene-expression variations in Down syndrome: impact on disease phenotypes. *Am J Hum Genet*. 2007 Sep;81(3):475-91. Epub 2007 Jul 19.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/17701894>
Free article on PubMed Central: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1950826/>
- Ensembl Human Map View: Chromosome 21
http://www.ensembl.org/Homo_sapiens/Location/Chromosome?chr=21;r=21:1-46709983
- Gardiner K, Costa AC. The proteins of human chromosome 21. *Am J Med Genet C Semin Med Genet*. 2006 Aug 15;142C(3):196-205.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/17048356>
Free article on PubMed Central: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3299406/>
- Gardiner K, Davisson M. The sequence of human chromosome 21 and implications for research into Down syndrome. *Genome Biol*. 2000;1(2):REVIEWS0002. Epub 2000 Aug 4. Review.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/11178230>
Free article on PubMed Central: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC138845/>
- Gilbert F. Disease genes and chromosomes: disease maps of the human genome. *Chromosome 21. Genet Test*. 1997-1998;1(4):301-6.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/10464663>

- Hattori M, Fujiyama A, Taylor TD, Watanabe H, Yada T, Park HS, Toyoda A, Ishii K, Totoki Y, Choi DK, Groner Y, Soeda E, Ohki M, Takagi T, Sakaki Y, Taudien S, Blechschmidt K, Polley A, Menzel U, Delabar J, Kumpf K, Lehmann R, Patterson D, Reichwald K, Rump A, Schillhabel M, Schudy A, Zimmermann W, Rosenthal A, Kudoh J, Schibuya K, Kawasaki K, Asakawa S, Shintani A, Sasaki T, Nagamine K, Mitsuyama S, Antonarakis SE, Minoshima S, Shimizu N, Nordsiek G, Hornischer K, Brant P, Scharfe M, Schon O, Desario A, Reichelt J, Kauer G, Blocker H, Ramser J, Beck A, Klages S, Hennig S, Riesselmann L, Dagand E, Haaf T, Wehrmeyer S, Borzym K, Gardiner K, Nizetic D, Francis F, Lehrach H, Reinhardt R, Yaspo ML; Chromosome 21 mapping and sequencing consortium. The DNA sequence of human chromosome 21. *Nature*. 2000 May 18;405(6784):311-9. Erratum in: *Nature* 2000 Sep 7;407(6800):110.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/10830953>
- Lam K, Zhang DE. RUNX1 and RUNX1-ETO: roles in hematopoiesis and leukemogenesis. *Front Biosci (Landmark Ed)*. 2012 Jan 1;17:1120-39. Review.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/22201794>
Free article on PubMed Central: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3433167/>
- Licht JD. AML1 and the AML1-ETO fusion protein in the pathogenesis of t(8;21) AML. *Oncogene*. 2001 Sep 10;20(40):5660-79. Review.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/11607817>
- Lubec G, Engidawork E. The brain in Down syndrome (TRISOMY 21). *J Neurol*. 2002 Oct;249(10):1347-56. Review.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/12382149>
- Map Viewer: Genes on Sequence
<https://www.ncbi.nlm.nih.gov/mapview/maps.cgi?O=human&MAPS=ideogr,ugHs,genes&CHR=21>
- Sawinska M, Ladon D. Mechanism, detection and clinical significance of the reciprocal translocation t(12;21)(p12;q22) in the children suffering from acute lymphoblastic leukaemia. *Leuk Res*. 2004 Jan; 28(1):35-42. Review.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/14630078>
- UCSC Genome Browser: Statistics
<http://genome.cse.ucsc.edu/goldenPath/stats.html>
- Valero R, Marfany G, Gil-Benso R, Ibáñez MA, López-Pajares I, Prieto F, Rullan G, Sarret E, González-Duarte R. Molecular characterisation of partial chromosome 21 aneuploidies by fluorescent PCR. *J Med Genet*. 1999 Sep;36(9):694-9.
Citation on PubMed: <https://www.ncbi.nlm.nih.gov/pubmed/10507727>
Free article on PubMed Central: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1734419/>

Reprinted from Genetics Home Reference:
<https://ghr.nlm.nih.gov/chromosome/21.pdf>

Reviewed: November 2013
Published: April 17, 2018

Lister Hill National Center for Biomedical Communications
U.S. National Library of Medicine
National Institutes of Health
Department of Health & Human Services